Technology Opportunity
Glenn Research Center • Cleveland • Ohio
Technology Transfer & Partnership Office
TOP3–00149

Atomically Flat Wide Band Gap Material

Technology

Processes to produce atomically flat silicon carbide (SiC), which can also improve other wide band gap (WBG) semiconductor materials.

Benefits

For all of the devices listed, poor material quality has been shown to reduce device performance and life. The atomically flat materials produced using NASA's processes are a significant improvement over commercially available materials, and should lead to improved device performance.

- For SiC surface-sensitive devices, some correlation has been demonstrated between device performance and material surface quality. Building these devices on NASA's atomically flat material should improve their performance. For example, a gas sensor recently fabricated using atomically flat SiC demonstrated record sensitivity not achieved on commercial SiC.
- For WBG devices built on SiC, it has been shown that surface steps in the parent SiC cause defects in subsequently grown Group III nitride layers. Eliminating the steps in the SiC should reduce defects in the nitride layers, leading to improved device performance and life.
- For nanoscale electronic devices and microelectromechanical systems (MEMS), as the device architecture gets smaller, the relative size of individual defects increases, and the effect of defects on device performance also increases. Nanoscale devices may require atomically flat material to achieve acceptable performance and life.

Commercial Applications

- SiC surface-sensitive devices:
  - Metal/oxide semiconductor field-effect transistors (MOSFETs)
  - Schottky diodes
  - Gas sensor devices
- WBG III nitride devices built on SiC substrates:
  - Blue lasers
  - Blue LEDs

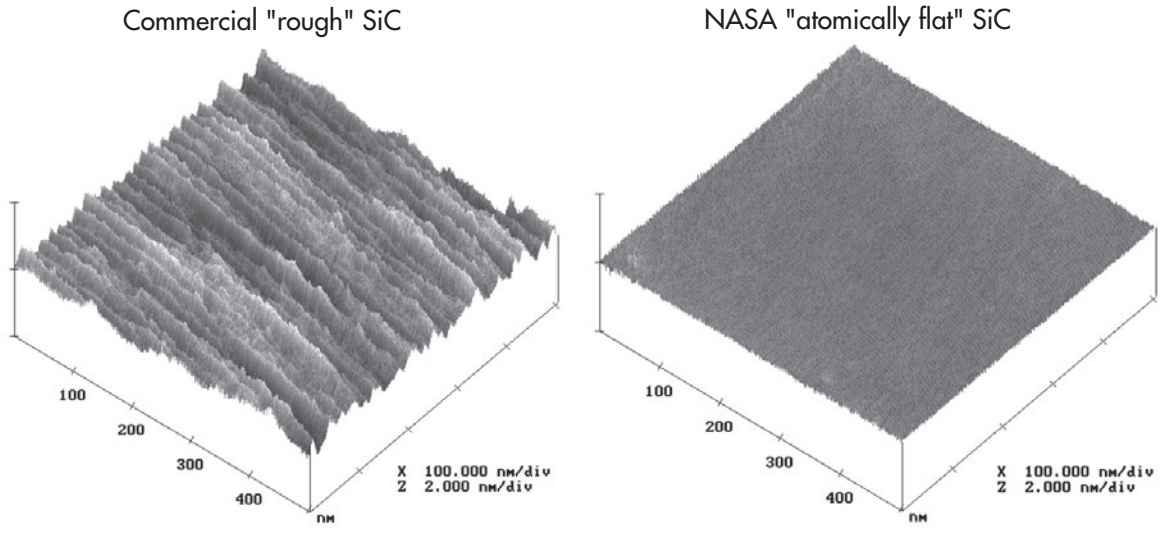

Figure 1.—Atomic force micrographs.

- High-power and high-frequency devices for radiofrequency (RF) amplifiers
- Nanoscale devices and MEMS

Technology Description

NASA researchers have developed and patented processes to eliminate the rough surfaces found on current WBG semiconductor materials, and to isolate defects in unused mesa areas. The atomic force microscope photographs shown in Figure 1 compare the surface of NASA's atomically flat SiC to that of commercially available SiC.

The first step in NASA's process to make step-free surfaces is to etch device-sized arrays of mesas into commercially available wafers. An attractive aspect of this technology is that this patterning step is the only extra step required for manufacturers to make these atomically flat surfaces. Next, by controlling the conditions, crystal growth is limited to the riser, or side, of each atomic step. The crystal at each step grows sideways until the step reaches the edge of the mesa, leaving behind an atomically flat surface. A schematic cross-sectional representation of this growth pattern is shown in Figure 2.

Some mesas cannot be made flat because they contain screw dislocation defects—so called because of the warped spiral stacking of the crystalline planes. The screw defects are not amenable to this flattening method; however, an added benefit of NASA's process is that screw defects are isolated into mesas that can be identified and avoided.

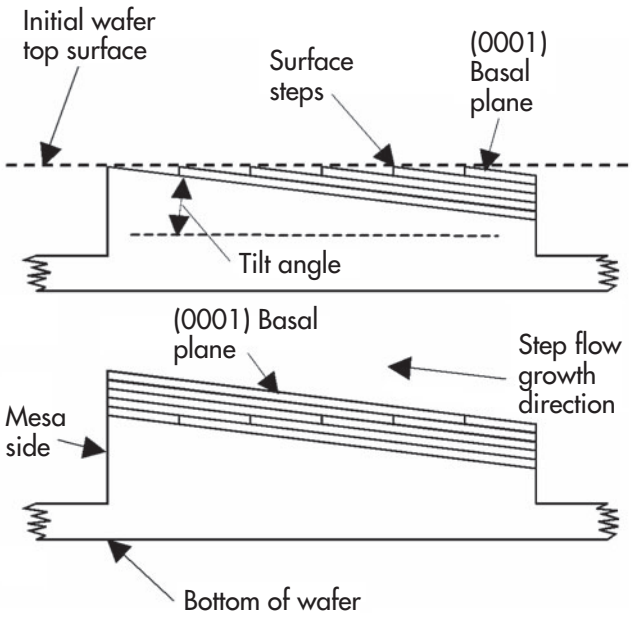

Figure 2.—Schematic of crystal growth.

NASA has demonstrated the process by flattening SiC mesas as large as 0.4 mm by 0.4 mm. NASA is continuing to develop this process to flatten SiC and is working toward demonstrating the benefits these flat surfaces will have on the performance of electronic devices.

Options for Commercialization

Initial industry contacts have replied with interest in working with this technology, so NASA Glenn has decided to pursue license agreements for its portfolio of atomically flat WGB material patents.

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LEW-15223-1, 15222-3, 16374-1, 16374-2, 17116-1, 17186-1, 17187-1

U.S. Patents 5,248,385; 5,636,800; 5,915,194; 6,165,874

Key Words

Wide band gap
Silicon carbide
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Blue laser
High-power electronics
Materials